tered near the northwest, northeast, southeast, and southwest corners of the State. It will be seen that the movement of a storm approximately along the northern border seldom produces precipitation over the "dry belt," while those that move along the southern border seldom fail to produce precipitation over the same area.

Of 16 LOWS that crossed the 105th meridian south of latitude 35°, 14 or 88 per cent produced precipitation over this region, while of 21 LOWS that crossed the 105th meridian between latitudes 35° and 40°, only 3 or 14 per cent produced precipitation over the "dry belt."

The late winter and early spring of 1912 furnished an unusually large number of the latter type of LOWS, there being no less than 10 of them within a three-months' period, all of which failed to cause precipitation over the region under discussion.

As illustrations, attention is invited to the weather maps of the following dates in the year 1912: February 20 and 24–25, March 2–5, 10–12, 13–14, and 20–24, April 19–20 and 27–28, and May 10–11. The storms of these dates caused general precipitation over their southeast and southwest, but missed the southern portion of the east mountain slope altogether.

One of these, the storm of March 11–12, is reproduced in connection with this discussion (fig. 6). It shows clearly this peculiarity in the precipitation area. A similar condition is illustrated in the combined maps of February 12–13, 1915 (fig. 7). With both of these storms the dry area extended northward into Colorado, but it was usually the case among the numerous types studied, that the dry area was somewhat more limited than this. The composite maps of the storms moving north of parallel 35 illustrate fairly well the average frequency of precipitation over this area and over the contiguous regions to the east, north, and west.

The combined maps of February 24–25, 1912 (fig. 8), give an example of a LOW being forced southeastward across New Mexico by incoming high pressure over the north, and producing general precipitation over the "dry belt," which would not have occurred had the LOW moved normally eastward. Compare the first position of this LOW (black of fig. 8) with the composite map of LOWS in that position (fig. 2); also with the LOWS of March 11, 1912 (black of fig. 6), and February 12, 1915 (black of fig. 7.)

Therefore the following general rule, applying only to the area under discussion, may be stated: *A storm area passing over or near New Mexico does not usually cause precipitation south of its center.*

Another condition that frequently produces precipitation over this region is a high-pressure area moving southeastward to Kansas or Oklahoma, preceded by southeast or east winds over this locality. The precipitation is generally light, and probably would not be of importance were it not for the fact that it occurs when conditions are strongly indicative of fair weather. When the incoming high-pressure area causes a large fall in temperature, precipitation may occur when the preceding humidity conditions are no more than normal. But usually it requires a preceding southeast or east wind, which seldom fails to increase the humidity over the region in question. Many such HIGHS cause overcast skies over southeastern New Mexico even when precipitation is absent.

A composite map of fourteen HIGHS, with their attendant precipitation areas, is here presented (fig. 9). In constructing this map, only such HIGHS as caused precipitation in western Texas or southeastern New Mexico were used. HIGHS of this class often bring about local rain in southeastern New Mexico when the skies are clear over the contiguous regions.

FOG IN RELATION TO WIND DIRECTION ON MOUNT TAMALPAIS, CAL.

By HERBERT H. WRIGHT, Assistant Observer.

[Dated: Weather Bureau, Mount Tamalpais, Cal., Feb. 15, 1916.]

The summit of Mount Tamalpais, rising to 2,600 feet above the Pacific Ocean within a distance of about 8 miles from the shore, possesses a distinct advantage for observational purposes over many other places that far exceed it in height. Owing to its proximity to so large a water surface it is specially suitable for observing and studying fog.[1]

Fog may be defined as visible particles of moisture floating in the atmosphere. In the vicinity of Mount Tamalpais fog usually occurs at an altitude of from 500 to 1,000 feet. It is therefore plainly visible from the Weather Bureau observatory near the summit of the mountain.

While fog occurs oftener and prevails for longer periods of time during the summer months, it occurs to some extent at all seasons. Table 1, compiled from records by the Weather Bureau on Mount Tamalpais, for the six years, 1910 to 1915, inclusive, shows the number of days in each month on which fog was observed in varying amounts below the elevation of the station. It will be seen from this table that the greatest percentage of fog occurs during the summer season.

TABLE 1.—*The number of days in each month on which fog was observed below the Weather Bureau station on Mount Tamalpais, Cal., 1910–1915, inclusive.*

Year.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Annual.
	Days	Days	Days	Days	Days	Days	Days	Days	Days	Days	Days	Days	Days.
1910	5	7	16	19	20	27	28	30	23	16	14	6	211
1911	0	4	7	13	9	26	29	27	19	11	11	6	162
1912	4	8	5	4	16	13	27	26	14	6	6	7	136
1913	5	10	14	16	22	25	27	25	17	16	10	12	199
1914	7	0	10	10	24	25	30	29	19	14	8	6	182
1915	5	2	6	11	18	25	26	26	20	20	12	7	178
Sums	26	31	58	73	109	141	167	163	112	83	61	44	1,068
Means	4.3	5.2	9.7	12.2	18.2	23.5	27.8	27.2	18.7	13.8	10.2	7.3	178

When a mass of air has been cooled to its dewpoint or lower, some of its invisible moisture condenses to form a visible cloud or fog. One of the various ways in which this cooling may be accomplished is that of the mixing of masses of air having different temperatures and relative humidities. In this process the character and the direction of the wind play a very important part. Entirely different conditions result when the warm air is driven out over the water to meet the cool air there than when the cool, moist air is carried shoreward, there to mix with the warmer air over the land. Mere direction alone, however, does not determine this; the character of the wind must also be considered. Fog very seldom forms when the wind is blowing from the east.

These east or northeast winds are not common along this coast, and occur only when a well-developed area of high pressure overlies Nevada and adjacent States. In the summer the air over the semiarid regions of Nevada and Utah becomes exceedingly warm and dry. Owing to the barometric gradient this warm, dry air flows down over California, and owing to the adiabatic heating often reaches the coast even warmer than when it started. Thus this air, under the influence of the east wind, goes out to mix with the cool air over the ocean, and being so dry has an enormous capacity for water vapor. The resultant temperature of the mixture is not low enough

[1] See the papers by *McAdie*, beautifully illustrated, in this REVIEW for 1900, 28: 283–6; 492–3; and 1901, 29: 24–5; 61–3; 104–6; and Weather Bureau bulletin "L".—C. A. jr.

to produce saturation and no fog appears. This is true during the winter season as well as the warmer part of the year. An anticyclone over Nevada in winter usually results in clear, cold weather for California, in contrast to the warming effect experienced in summer under a similar distribution of pressure. While these northeasterly winds are extremely cold, they are as a rule quite free from moisture and are able to absorb considerable water vapor before becoming saturated, but of course not to the extent that we find in summer when the air is both dry and warm.

Table 2 gives an idea of the difference in temperature and relative humidity during the summer between the land air and the air over the ocean. Point Reyes Light, 22 miles northwest of Mount Tamalpais, is on a point of land extending half a mile or more into the Pacific, and the Weather Bureau station there is on a bluff only 490 feet above sealevel. The record for Mount Tamalpais was made at an elevation of approximately half a mile (H=2,375 feet).

The facts (*a*) that the specific heat of water is large, (*b*) that clear water is deeply penetrated by solar radiation, and (*c*) that much of the heat absorbed is consumed by evaporation, combine to keep water temperatures from rising very high. Hence both radiation by the water and heat conduction from it are kept correspondingly low. The land, on the other hand, is rapidly heated and almost as rapidly warms the lower layers of air by radiation and conduction. Then by subsequent convection the air is heated to a considerable altitude. It has been observed that fog is more likely to occur when the temperature above is higher than at sealevel. Also that fog probability varies directly as the difference in temperature between the lower and upper air layers increases.

TABLE 2.—*Comparison of daily temperatures and relative humidities at Mount Tamalpais and at Point Reyes Light, Cal., during August, 1914.*

Date.	Temperatures.						Mean relative humidity.	
	Maximum.		Minimum.		Mean.			
	Mount Tamalpais.	Point Reyes.	Mount Tamalpais.	Point Reyes.	Mount Tamalpais.	Point Reyes.	Mount Tamalpais.	Point Reyes.
	°F.	°F.	°F.	°F.	°F.	°F.	P. ct.	P. ct.
1	91	66	74	49	82	58	26	85
2	80	55	49	48	64	52	23	95
3	72	65	48	54	60	60	78	84
4	83	55	65	49	74	52	33	99
5	90	55	72	50	81	52	30	86
6	82	59	71	50	76	54	22	80
7	83	57	66	50	74	54	24	81
8	67	57	53	52	60	54	62	96
9	71	58	51	53	61	56	42	96
10	76	57	66	52	71	54	51	92
11	86	58	70	51	78	54	27	92
12	79	57	69	52	74	54	20	91
13	77	58	67	52	72	55	26	91
14	80	60	71	52	76	56	42	85
15	82	59	73	53	78	56	16	84
16	83	58	72	50	78	54	14	78
17	81	57	65	50	73	54	30	80
18	72	54	60	48	66	51	36	92
19	62	58	46	51	54	54	60	91
20	72	58	57	49	64	54	47	85
21	79	56	62	49	70	52	38	100
22	82	55	72	49	77	52	32	94
23	80	55	68	49	74	52	34	91
24	70	56	46	50	58	53	34	94
25	69	55	58	49	64	52	34	95
26	67	55	45	50	56	52	37	95
27	73	53	60	50	66	52	59	98
28	77	53	55	50	66	52	51	100
29	76	54	65	49	70	52	40	94
30	68	53	48	49	58	51	68	100
31	54	56	45	50	50	53	87	93
Mean	76	57	61	50	69	54	39	91

The greatest differences in temperature and relative humidity between the masses of air in question are to be found during the summer season. Owing to the shortness of the days in winter, the land surfaces can not absorb as much heat as they radiate into space during the long nights. This, together with the fact that the sun is so far south of the Equator, causing a small angle of incidence to the rays received, does not permit the warming of the air over the land to any great height. In fact, the ocean air is now warmer than the air over the land, as will be seen by referring to Table 3.

During the summer, when the air over the ocean is cooler than that over the land in the vicinity of Mount Tamalpais, the prevailing west wind produces a mixing of air masses differing greatly in temperature. Fog then forms when the resulting temperature is at the dewpoint of the air mass or lower. Thus the wind direction, and consequently its character, which is determined by the direction, are great factors in the production of fog. From May to September the familiar land- and sea-breeze prevails. By referring again to Table 1 it will be observed that it is during this period that fog is most frequent. The sea-breeze begins early in the forenoon and with it comes the fog. It often lasts well into the night. The land breeze is the weaker of the two and sometimes fails altogether. It is then too weak to reverse the action of the sea-breeze and little if any fog is dissipated during the night. The popular impression is that the wind "goes down" late in the evening and the land breeze, being so weak, is not felt.

TABLE 3.—*Comparison of daily temperatures and relative humidities at Mount Tamalpais and at Point Reyes Light, Cal., during January, 1916.*

Date.	Temperatures.						Mean relative humidity.	
	Maximum.		Minimum.		Mean.			
	Mount Tamalpais.	Point Reyes.	Mount Tamalpais.	Point Reyes.	Mount Tamalpais.	Point Reyes.	Mount Tamalpais.	Point Reyes.
	°F.	°F.	°F.	°F.	°F.	°F.	P. ct.	P. ct.
1	38	49	30	42	34	46	100	86
2	47	52	36	42	42	47	100	100
3	43	52	37	44	40	48	100	92
4	42	54	35	41	38	48	100	97
5	39	51	34	44	36	48	100	89
6	40	52	35	42	38	47	93	85
7	41	50	38	44	40	47	100	90
8	42	50	37	44	40	47	100	95
9	39	51	32	41	36	46	99	100
10	33	45	29	35	31	40	93	77
11	37	47	30	42	34	44	74	76
12	40	46	32	40	36	43	92	100
13	43	46	38	43	40	44	100	100
14	43	48	33	42	38	45	98	85
15	38	50	32	41	35	46	99	90
16	44	50	36	43	40	46	92	82
17	43	50	34	43	38	46	98	72
18	35	47	32	40	34	44	92	93
19	39	48	32	40	36	44	96	92
20	39	51	32	42	36	46	90	91
21	38	49	34	42	36	46	98	94
22	46	49	38	42	42	46	100	100
23	47	52	44	45	46	48	100	100
24	46	54	44	49	45	50	100	100
25	46	50	32	44	39	47	92	80
26	34	46	28	40	31	43	60	79
27	39	48	27	36	33	42	100	98
28	32	45	27	35	30	40	91	94
29	32	44	27	35	30	40	92	91
30	36	47	27	37	32	42	92	78
31	40	52	30	37	35	44	64	76
Mean	40	49	33	41	37	45	94	90

In observing the formation of fog from Mount Tamalpais it has been noticed that the fog often starts a short distance from the shore and then comes inland. Occasionally the fog forms as far as 20 miles out at sea, increasing in amount as it comes steadily landward in the form of a high bank or wall. This formation is probably of different origin from that referred to in the preceding paragraphs. It is due no doubt to the upwelling of relatively cold water some distance offshore. The ocean air, already near the point of saturation, is cooled to its dewpoint when it comes in contact with this relatively cold water. The fog then formed persists unbroken for long periods of time. When the air in which this fog floats is drawn inland to replace the heated air rising over the hot interior valleys in summer, this fog, already formed, moves inland with it and does not dissipate until the sun literally dries it up from above. The wind direction naturally determines whether or not fog of this kind comes inland.

A marked case of fog formation and dissipation with relation to the shifting of the wind occurred in December, 1915. On the 20th the temperature on the mountain began to rise slowly. The following morning at 5 o'clock the thermometer recorded almost 1 degree higher than the preceding afternoon. Also considerable fog had formed below at an elevation of about 800 feet. By 5 p. m. the temperature had risen to 54°F., and conditions resembled those usually present during the summer months, the period of greatest fog prevalence below. Early the following morning the wind changed to the northeast, and by mid afternoon the fog had dissipated. At 5 a. m. the next day, December 22, it was observed that some fog had formed during the night. The temperature here was 53°F., while at San Francisco, 14 miles southeast of here, it was 50°F. The wind during the night and up to 7 o'clock in the morning was from the north, when it veered to the northeast. By 8:30 a. m. the fog below had disappeared. The temperature continued to rise, and reached 59°F. in the middle of the afternoon, and was 57°F. at 5 p. m. At San Francisco the temperature at 5 p. m. was 60°F., and had been as high as 64°F. in the middle of the day. No fog formed during that day. Soon after noon the wind backed to the northwest and continued from that quadrant until 9 a. m. of the 23d. At 5 o'clock that morning the temperature on the mountain, which represents the temperature of the upper air, was 56°F., equal to temperatures on many mornings in the middle of summer. At San Francisco the temperature at the same time was 51°F. About half the surrounding country was covered with fog. The wind swung to the northeast at 9 a. m., remaining there till 1 p. m., when it backed to the north. The fog cleared away before noon. The weather remained warm throughout the day, the wind continuing light from the north until 4 a. m. of December 24, when it veered to the northeast, remaining there until 11 a. m. Very little fog formed during the night. At 5 o'clock that morning the temperature here was 54°F., while at San Francisco it was 10 degrees lower. By 3 p. m. a fog bank could be seen about 20 miles out on the ocean, moving landward. Signs of the wind backing to the northwest were noticed at 3:30 p. m. By 5:30 it had gone to the northwest, and by 7 p. m. the direction was west. Also by 5 p. m. the fog had reached the shore and in another hour completely covered the ocean and land to the south and southeast of Mount Tamalpais. The temperature fell during the night of the 24th, being 49°F., at 5 a. m. of the 25th. At San Francisco it was 1 degree warmer. Simultaneously with the return to normal winter temperatures, i. e., warmer at sealevel than at higher altitudes, the fog began to dissipate and was gone by midafternoon.

The foregoing case bears out the hypothesis that the temperature of the upper air must be higher than that of the lower to produce proper conditions for fog formation, and also shows the part the direction of the wind plays with regard to fog formation and dissipation.

ON THE SO-CALLED CHANGE IN EUROPEAN CLIMATE DURING HISTORIC TIMES.[1]

By H. H. HILDEBRANDSSON.

[Presented to the Royal Society of Sciences of Upsala, Nov. 5, 1915.]

INTRODUCTION.

It is a well-established fact that climate has undergone very great changes in all the lands of the world during those distant times with which geologists are concerned. Even during the relatively short period that has elapsed since the end of the glacial epoch it has been possible to verify quite considerable variations in the Scandinavian countries. For example, it is well established that since the glacial epoch the climate of Sweden was at one time much warmer than it is to-day. In the peat-bogs have been found hazelnuts or filberts (*Corylus avellana*) as far as Lapland, the *Trapa natans* occurred in the lakes of Sweden up to the latitude of Upsala, and stumps of pine trees are found in the Scandinavian Alps up to the present limits of the birches, etc. These climatic variations are explained by the great changes in distribution of land and sea. It is clear that the climate must have been other than as it is at present when the Baltic occupied the greater portion of southern Sweden, and that it must have been different when this great lake was filled with fresh water than it was at the time when it formed a gulf of the sea filled with salt water. Archæologists find that the peninsula has had almost the same coast line—except the coasts of Norrland—since the beginning of the Iron Age, that is, at a period estimated as preceding our own by 2,500 years. Since that epoch there has been no notable change in the distribution of land and water. It remains to determine whether the climate has undergone a change during this period, i. e., historic times.

This question has been the subject of lively discussion for a long time and in recent years it has become somewhat acute, particularly through the recent researches of O. Pettersson. He seeks to prove that our climate undergoes a secular variation of about 18 centuries, due to a corresponding variation in the heat given out by the sun. This theory has called forth other researches concerning which we shall speak below.

Here I shall endeavor to present the results arrived at by a study of the question. We shall not consider accidental or periodic variations which are well recognized and exist everywhere. In every country there are years, even series of years, which are warm or cold, dry or moist, etc., and several more or less regular periods have been shown to exist, such as that of Brückner, that of solar spots and other shorter ones recently studied by Wallén. *In the present study we shall endeavor to determine whether or not there has been a continuous change in climate in one direction during historic times; in other words, whether the climate of Europe is improving or deteriorating.*

The question would be easily answered if we had continuous meteorological observations from several centuries back down to the present. But even the invention of meteorological instruments goes back scarcely

[1] *Translated from* Nova Acta Regiæ Societatis Scientiarum Upsaliensis, Series IV, v. 4, no. 5, Upsala, 1915. 31 p., 3 pl. 4°.—C. A., jr.